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Guidance and Navigation (G&N) and Service Propulsion system (SPS) restart changes memorandum for Apollo Operations Handbook

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Memorandum

CB/Swigert

TO : CF22/Chief, Spacecraft Systems Branch

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In reply refer to:
CF221-8M-122

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SUBJECT: AOH G&N thrusting procedures - SPS Restart

REFERENCES: a. AOH 101 dated March 1, 1968, and AOH 103 dated April 1, 1968
b. Memorandum PD6-8M-121, subject "Restart constraint on the Block II Service Propulsion System," dated March 15, 1968

The S/C 101 and 103 AOH's have left the backup procedures for no ignition or premature shutdown of the SPS undefined. This memo discusses some of the constraints associated with the G&N system (Program Sundisk) during thrusting and suggests a possible backup procedure.

There are essentially two types of G&N controlled burns:

a. Timed burns (where the burn length as computed by the CMC at TIG -5 seconds is less than or equal to 6 seconds)

b. Monitored burns (where the burn length as computed by the CMC at TIG -5 seconds is greater than 6 seconds)

During timed burns (see Enclosure 1), the engine is turned off when the thrusting time (t_{on}) has expired. If ignition did not occur or should a premature shutdown occur, it would not alter the CMC sequence. There is no monitor running to verify that the SPS has responded to the engine on discrete. There is also a 5-second time constraint between SPS burns (see Reference b). Therefore, it seems unlikely that the G&N system could be used to control a restarted SPS in the short burn case.

During long burns (see Enclosure 2) the length of burn is continually updated at 2-second intervals until t_{go} becomes less than 4 seconds. In addition, a monitor routine in the CMC is used to verify that the SPS has responded to the engine on discrete and to determine if premature shutdown has occurred. If the monitor detects an SPS failure, the CMC notifies the crew by flashing a V50N99 display and provides an opportunity to reignite the engine under CMC control. Tied to the SPS ignition is the transition from the RCS DAP to the TVC DAP. Since the RCS DAP is turned off shortly after ignition, the CMC maintains ullage by setting the proper (as determined by the THC input) "jet on" discretes under

program control. These jets stay on until the ΔV monitor senses sufficient thrust. If ignition did not occur, ullage would continue until the RCS-DAP was again turned on and operating (nominally a period of approximately 7 seconds). Performing the ullage in this manner provides no attitude hold, and due to cg. offset, the vehicle will rotate away from the prethrust orientation. (Sliderule calculations show the amount of rotation in pitch, the axis which is affected most, to be on the order of 5°.) When the RCS-DAP is restarted the maximum D.B. is automatically set. The vehicle under CMC control would maintain an alignment displaced from the prethrust orientation by $5 \pm 5^{\circ}$. If the pilot were to continue ullage and then reinitiate ignition, he could expect a misalignment of 10° at ignition.

If the ΔV monitor sensed thrust build-up for one 2-second pass before thrust cutoff, the CMC would remove the ullage command but there would still be a delay of at least 7 seconds before the RCS-DAP began control and held the vehicle at the attitude it was in when the RCS DAP regained control. What this attitude would be is unpredictable since it is expected that the SPS would impart some rates to the vehicle prior to cutoff. In addition, the TVC DAP would try to maintain control of the vehicle but would be unsuccessful without SPS thrust. The trim estimator would most likely be in error which would cause undesirable transients during the first portion of a restarted burn (see Item 5.4 DAP Performance Presentation of the Sundisk CARR Minutes, dated February 16, 1968).

Any restart procedure should provide a method for returning the vehicle to the burn attitude, a delay of at least 5 seconds (as required by Reference b), and a method for initiating and controlling the thrust magnitude. It is understood that it may not be desirable to attempt reignition and such situations will be covered by Mission Rules, Flight Procedures, and circumstances. However, the full capability of the G&C system must be available for use if required. In order to provide a SPS restart capability, it is recommended that the following procedure be simulated in order to establish a pointing accuracy, and to demonstrate adequate monitoring, proper switching, and reasonable crew workload. The results of the simulation should provide a basis for modifying the existing AOH procedures or suggest additional procedures.

Recommended backup procedure for premature SPS thrust cutoff during G&N controlled burn using the Sundisk 282 program.

STEP	PROCEDURE	REMARKS
ECO (Engine Cutoff)	SC CONT - SCS	SCS Att Hold selected Engine Control removed from G&N system
	FCSM (2) - RESET/ OVERRIDE	
	FCSM - SPS A (SPS B)	
ECO +5 sec	If Fl V50 N99	Indicates burn was being monitored and "Engine on" discrete removed
	SC CONT - CMC	Returns Engine Control to the G&N system
	Ullage TBD sec	
	Key ENTER	Authorizes immediate ignition
or	SCS TVC - AUTO	Provides SCS Auto TVC (Vg will count down even under SCS control)
	Ullage TBD sec	
	THRUST ON - PUSH	Ignites SPS under SCS control

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Enclosures 2

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SHORT (TIMED) BURNS ($t_{on} \leqslant$ 6 sec) - SEQUENCE OF SIGNIFICANT FUNCTIONS

TIME	FUNCTION	REMARKS
TIG -30.5 sec	CMC calls Average G	Thrusting navigation starts. Accelerometer sampled every 2 seconds until Average G is terminated (done by V37 selection of a new program)
TIG -15 sec	4 jet ullage manually initiated	Through DAP or Direct Ullage
TIG -5 sec	CMC computes t_{on} V50N99 (Engine on enable) Flashes	t_{on} used to determine if burn is short ($t_{on} \leqslant$ 6 sec) or long ($t_{on} >$ 6 sec)
Ignition	CMC sets SPS on discrete RCS-DAP turned off (T6 overflow) - ullage (based on DAP data and present THC inputs) continues. TVC DAP started	Ignition occurs when ENTER response to V50N99 Flash is given and $T_{now} \geqslant$ TIG The RHC & THC inputs to the CMC are no longer interrogated. The CMC will maintain the ullage until Ignition +1.7 sec. (Since the RCS-DAP is turned off there is no RCS attitude hold during this period.)
Ignition +.61 sec	Roll Attitude established	Roll attitude held within $\pm 5^{\circ}$ of present CDUX value (Roll jets will not be fired until Ignition +1.1 sec)
Ignition +1 sec	The SCS disables Pitch and Yaw auto jet control	Requires ignition command (grounding) to the SPS Propellant control valves, arming of the prevalves, and no FCSM-ECO.
Ignition +1.1 sec	CMC begins to control roll jets if required	The jet firings alternate between the A/C and B/D quads and between + and - rotations. Max continuous jet on time for a set of quads is 2.5 sec. (Quad selection in the DAP data load does not affect roll jet operation during TVC)

ENCLOSURE I

TIME	FUNCTION	REMARKS
Ignition +1.7 sec	CMC removes ullage jet commands	This function independent of THC inputs
Ignition +t_{on} (C/O)	CMC removes the SPS on discrete (Engine Cutoff)	Engine cutoff on time as calculated at TIG -5 sec
C/O +1 sec	The SCS enables the pitch and yaw auto jet control	
C/O +2.5 sec	RCS DAP started SPS Engine bell returns to servo null	TVC DAP turned off. TVC enable discrete removed.
C/O +4.2 sec	RCS-DAP initialized and jet control may begin (Max DB)	Min DB set upon PRO from V16N40 display (Post Burn)

LONG (MONITORED) BURNS ($t_{on} > 6$ sec) - SEQUENCE OF SIGNIFICANT FUNCTIONS

TIME	FUNCTION	REMARKS
TIG -30.5 sec	CMC calls Average G	Thrusting navigation starts. Accelerometer sampled every 2 seconds until Average G is terminated (done by V37 selection of a new program)
TIG -15 sec	4 jet ullage manually initiated	Through DAP or Direct Ullage
TIG -5 sec	CMC computes t_{on} V50 N99 (Engine on enable) Flashes	t_{on} used to determine if burn long ($t_{on} > 6$ sec) or short ($t_{on} \leq 6$ sec)
Ignition	CMC sets SPS on discrete RCS-DAP turned off (T6 overflow) - ullage (based on DAP data and present THC inputs) continues. TVC DAP started. ΔV Monitor initiated.	Ignition occurs when ENTER response to V50N99 Flash is given and $T_{now} \geq$ TIG. The RHC & THC inputs to the CMC are no longer interrogated. The CMC will maintain the ullage until the first successful pass (i.e., $\Delta V > .6435$ m/sec in a 2-sec interval) through the ΔV monitor.
Ignition +.61 sec	Roll attitude established	Roll attitude held within $\pm 5^{\circ}$ of present CDUX value. (Roll jets will not be fired until Ignition +1.1 sec)
Ignition +1 sec	The SCS disables Pitch and Yaw auto jet control	Requires ignition command (grounding) to the SPS Propellant control values, arming of the prevalves, and no FCSM - ECO.
Ignition +1.1 sec	CMC begins to control roll jets if required	The jet firings alternate between the A/C and B/D quads and between + and - rotations. Max continuous jet on time for a set of quads is 2.5 sec. (Quad selection in the DAP data load does not affect roll jet operation during TVC)

ENCLOSURE II

TIME	FUNCTION	REMARKS
$t_{go} < 4$ sec	ΔV monitor turned off (termination of burn is based on time)	T_{go} computed every 2 sec after a successful 2nd pass through the ΔV monitor until $t_{go} < 4$ sec
$T_{go} = 0$ (e/o)	CMC removes the SPS on discrete (Engine Cutoff)	
C/O +1 sec	The SCS enables the Pitch and Yaw auto jet control	
C/O +2.5 sec	RCS DAP started SPS Engine bell returns to servo null Possible update of the R03, N48 Pitch and Yaw trim values	TVC DAP turned off TVC enable discrete removed The trim values will be updated if $t_{go} \geq 10$ sec when the ΔV monitor was successfully passed, and $t_{go} \leq 4$ sec when the engine is turned off.
	SPS Engine bell returns to servo null	TVC enable discrete removed
C/O +4.2 sec	RCS-DAP initialized and jet control may begin (Max DB)	Min DB set upon PRO from V16N40 display (Post Burn)